**Deep Sea Slide Show Script**

Slide 1 Black smoker (photo by ALVIN, 1991)

At the end of the 1 970’s “black smokers” were seen for the first time precipitating and forming what we call mineral deposits. These mineral deposits are rich in copper, zinc, iron and some silver and gold. The minerals formed are sulfates such as anhydrite and barite, sulfides such as pyrrhotite and chalcopyrite (fool’s gold) and silica.

Today, I invite you to join in our scientific quest to understand the formation of these mineral deposits and share some of the discoveries made in the last 20 years. To give you a taste of the kind of adventure scientists live while working on the ridge systems, I will lead you through a day under the sea to visit the hydrothermal vents and their incredible animal communities.

Slide 2 Research vessel ATLANTIS II in port in Astoria, Oregon (photo by V. Robigou, 1988)

To study black smokers scientists such as geologists, biologists, geophysicists and chemists need to get to great depths. Most spreading centers are located between 2000 and 5000 m deep in the oceans. In order to better understand how black smokers are formed and what kind of life they support, scientists need to first see where they are located and understand the geology around them. To get to them, we use a submersible. The research vessel ATLANTIS II, run by the Woods Hole Oceanographic Institute, is the mother ship for the famous ALVIN submersible. It is on the dock in Astoria, Oregon that this adventure starts. Our goal is to dive on the Juan de Fuca Ridge located in the Pacific Ocean about 200 miles away from the coast of Oregon, Washington and British Columbia, Canada. Hydrothermal vents were discovered on this ridge in the early 1 980’s and have been studied since. A large multidiscipinary group of scientists from the University of Washington and NOAA has used ALVIN to visit these hydrothermal vents. Note the A-frame on the fantail of the ship. It’s with the A-frame that the submersible ALVIN is lowered into or raised from the sea every day.

Slide 3 ALVIN submersible in its hanger (photo by V. Robigou, 1995)

This is the ALVIN submersible ready for a dive in early morning. The ALVIN can take three persons to the seafloor. It is about 8 m long, 3.5 m high and the titanium sphere in which the divers and pilot will spend the day is about 2 m in diameter. The sphere seems quite small for 3 persons especially because there are so many panels and instruments inside the sphere. The titanium sphere is pressure-resistant and pressurized like an airplane cabin. Outside in the front of ALVIN, you can see the two manipulators or arms which will enable the pilot to grab rock and biology samples for the scientists as well as deploy instruments on the seafloor or measure temperature of the hydrothermal fluids. Also note the center porthole which is used by the pilot for flying the submersible. Scientists also have a porthole they can use to make observations and they are located on the sides of the sub. There are many strobe lights on top of the sub to illuminate the seafloor because at 2000 m depth, it is pitch-dark There are also fixed cameras looking in different directions and documenting everything done during the dive. Last, you can see the very important basket in front of the sub which will be used to collect samples during the dive.

Slide 4 Scientist embarking for a dive (photo by V. Robigou, 1988)

It is 7:30 am and the ALVIN has been checked by the ALVIN pilots and engineers, it has been rolled out of the hanger and the scientists are embarking for today’s dive. The swimmers standing by the hatch of ALVIN are helping the scientists get in and checking out all communications systems between the submersible and the surface before the sub is launched.

Slide 5 – vero going into ALVIN

ALVIN is ready to go. The hatch has been sealed and the A-frame moves the sub over board for the launch. The weather is fair today and the dive should be good. The scientists are checking on cameras, voice recorders and their planned experiments as the pilot goes one more time through all the ALVIN systems making sure everything is safe and in good order for the day before submerging.

Slide 6 ALVIN is launched at the surface of the ocean (photo by V. Robigou, 1988)

ALVIN is lowered in the water by the A-frame. The photo is taken from the accompanying Zodiak watching over the last few launching steps.

Slide 7 ALVIN is the water (photo by V. Robigou, 1988)

ALVIN is now free from the A-frame and autonomous. The swimmers are checking one more time the seal on the hatch and communications between the sub and the surface. They will then dive off the sub and join the Zodiak which will take them back on board the ATLANTIS II for their regular watches until the ALVIN surfaces at the end of the day.

Slide 8 Scientist in the sub (photo P. Hickey, 1995)

It is going to take approximately 1 .5 to 2 hours to reach the bottom. Battery power is not used to go down or come back up to the surface. But, a combination of weights tied outside of the sub, air pockets under the carapace of ALVIN and natural buoyancy of the sub are used to descend and ascent. Battery power is used to fly above the seafloor and to conduct experiments on the bottom, as well as for lighting during the dive. As the submersible goes deeper and deeper, we loose sight of light and the water soon turns completely dark. The light only penetrates water for the first few hundred meters. Along the way we can watch jelly-fishes, shrimps and salps. When the water becomes really dark, we travel for a while in a level where many small organisms are bioluminescent and attracted by the large intruder coming through their kingdom. The last hour is dedicated to reviewing the plan of the dive with the pilot and discussing with him how to optimize our battery power and get as much done as possible in the few hours we will spend on the bottom.

Slide 9 On the bottom of the ocean (photo by ALVIN, 1988)

Finally we land slowly of the bottom without disturbing the fine veneer of sediment that covers the frozen lava. Now, we turn the lights on to orient ourselves and check out the in-hull navigation system to decide which direction to go. Through the portholes, we can see at a distance of 8 to 1 0 m. It is easy to get lost on the dark, uniform lava floor. The pilot and scientists are now concentrating on any signs that will indicate where we are and help us find our way on the bottom. It is very difficult to do geological mapping on the seafloor because we can see only to such a limited distance. It can be compared to mapping a mountain range at night from a car window with a torch light. On this photograph is typical seafloor made of basaltic rock, with an occasional fish swimming in search for food.

Slide 10 On the bottom of the ocean (photo by ALVIN, 1988)

As the submersible progresses along the seafloor we encounter various lava flow types. Here, the lava shows elongated folds at the surface.

Slide 11 On the bottom of the ocean (photo by ALVIN, 1988)

Now we enter a field of “pillow” lava which is the most typical texture of lava on the seafloor Basaltic lava is viscous and oozes on the seafloor. When in contact with cold sea water, the surface of the lava cools down rapidly and forms a crust on the flowing lava. These processes produce round-shaped blocks called “pillow” lava.

Slide 12 On the bottom of the ocean (photo by ALVIN, 1991)

A beautiful pillow lava has spread over a flat sheet flow. Note the presence of thin, white sponges in this area.

Slide 13 On the bottom of the ocean (photo by ALVIN, 1988)

Still travelling on basaltic floor. The biology consists of sponges including tall vase sponge on which brittle stars are climbing. Still no sign of hydrothermal activity or fractures on the seafloor.

Slide 14 On the bottom of the ocean (photo by ALVIN, 1988)

We are reaching a more complicated area with broken-up blocks of lava and a spider crab. Spider crabs are found all through the ocean even at great depths (2200 m here). They are scavengers and usually a good indicator of a close-by food source.

Slide 15 Hydrothermal vents (photo by ALVIN, 1988)

This spider crab is busy eating the worms that build large living bushes on the basalt. These worms are tube worms and they are indigenous to hydrothermal vents areas and live in fluid up to 350C. They are formed by a lophophore protected by a chitinous tube. Their red gills sway in the warm fluids from which they filter the nutrients they need to survive and live in this environment.

Slide 16 Hydrothermal vents (photo by ALVIN, 1988)

Another healthy bush of tube worms on the basaltic floor. Note the white patches to the right side of the image. These patches are bacteria lining the sides of cracks and fractures from which the hot fluid comes.

Slide 17 Hydrothermal vents (photo by ALVIN, 1991)

By following the patches of tube worms we finally reach the sulfide mineral deposits with their black smokers. These deposits have probably been around for quite a while - hundreds or thousands of years because they are so large. The minerals that have accumulated over time have constructed mounds tens of meters in diameter and tens of meters high. It is at the top of the mound that are located the active chimneys or black smokers. On this slide you can see a black smoker on the left and several tiers of sulfide build-up on the right side. Note that biological communities cover the sulfide mounds. Because warm fluids percolate through the sulfides, these animals thrive on the active mounds.

Slide 18 Hydrothermal vents (photo by ALVIN, 1988)

Another example of a black smoker on top of an active sulfide mound. The black-colored plume rising from the orifice of the sulfide chimney is the result of the buoyant mineral-laden hydrothermal fluid at 3500C mixing with the cold 20C sea water. The black color is due to small particles of sulfide minerals precipitating out of the hot fluid when it mixes with the sea water.

Slide 19 Hydrothermal vents  (photo by ALVIN, 1991)

This smoker has a white plume rather than a dark plume, probably because the temperature of the hot fluid is lower and the minerals precipitating might be sulfates (which have a white color) rather than sulfides in typical black smokers.

Slide 20 Hydrothermal vents (photo by ALVIN, 1991)

Here is a beautiful site on top of one active sulfide mound. In the center are several platforms covered by bacteria and many species of worms. On the right side and in the background several meters high sulfide chimney and on the left side a marker letter “H” that we deployed with the sub. By leaving markers behind on specific sites we can return to the exact same spot during a later dive to check on the changes happening in these very active areas. We can also return to the same site several years later when we get new dives and compare the exact same chimney for changes. This way we can start to understand how these processes evolve through time. For example, how fast do these sulfides accumulate? If the geology changes a lot with time, what effects does it have on the biological communities? Do smokers “smoke” for a long time? Do biological communities migrate if the hot fluid stops coming through to the seafloor? We also use markers for scale to get an idea of the size of these deposits since it is very difficult to have a good idea of scale when you are studying such a system with the limited view you get through a porthole or the eye of a camera.

Slide 21 Hydrothermal vents (photo by ALVIN, 1995)

Close-up of a tube worm community established on an active sulfide mound.

Slide 22 Hydrothermal vents (photo by M. Smith and J. Delaney, 1988)

This is a digital image that was produced using a very special camera sensitive to very low levels of light. The picture was taken with a CCD camera mounted on the basket of ALVIN and all lights on ALVIN turned off. The mannequin at the foot of the mineral deposit is human size and we deployed it at the base of this mound to use as a scale. The deposit is about 10 meters high or as high as a 2- to 3-story house. It is a very large deposit and we would have never figured out its size without this trick and the help of the CCD camera. This image was produced in 1 988 and it was the first time such an experiment was ran. It was the first time scientists could get a good idea of how big these deposits could be.

Slide 23 Hydrothermal vents (scientific rendering by V. Robigou, 1993)

This is a scientific rendering of another sulfide mound found off the coast of Washington by the University of Washington scientific team. This drawing was composed by using video records during a dive and piecing together all the visual information we had on this site to get a general image of the site. It is the tallest, single active sulfide structure found in the Pacific Ocean as of today. For scale I have included on the drawing the ALVIN and you can see how small the submersible looks compared to this huge tower of sulfide. Imagine how small the divers must have felt when they discovered this site. It is so big and so much bigger than the little mound to the side at its base that the pilot and scientists named this site Godzilla and Bambi. Dr. J. Delaney and I were on the dive that discovered this site in 1991. During the dive, we can only see a limited part of the environment from the porthole, but we started getting very excited when we realized we were looking at a sulfide wall for such a long time. We started at the base of the mound and asked the pilot to slowly move the submersible up to see how tall this mound was. We first wanted to get an idea of the size of the structure and how active it was. So, while the pilot was exploring the structure, we kept our eyes going from the altimeter inside the sub to the porthole to make observations. During the first trial, we were going up and still looking at the vertical wall of sulfide, and the altimeter was showing altitudes of 10 m, 15 m, 20 m, 25 m then we were getting lost in a cloud of black smoke. we were getting very excited realizing that we had encountered the biggest sulfide structure we had ever seen. To make sure, we asked the pilot to take the submersible back to the base and start the ascent along the wall again just to make sure we were getting good readings on the altimeter. On the second trial, we saw the sulfide wall for more than 33 m. We were now getting truly excited and beginning to figure out we had found something exceptional. At 33 m, again the sub was engulfed in black smoke. So, we went back down one more time and ascended very slowly on the other side of the structure. We also observed that the structure was particularly active and we could see smoke coming out of horizontal extensions on the structure at 20 m of altitude. On this last run, we reached the top of the structure at 41 m, and could spend time sampling the black smokers all the way on the top, we collected fluid samples and measured fluid temperatures of 336!C. We had found the tallest active sulfide mound and it was as tall as a 10- to 12-story high-rise. We were thrilled!!!!!

Slide 24 ALVIN in action (photo by ALVIN, 1991)

This photograph was taken by ALVIN while the pilot is sampling some hot fluid from a black smoker. You can see both arms in the field of view as well as the basket in front of the sub filled with the special bottles used for fluid sampling.

Slide 25 Results from the dive (photo by R. Holcomb, 1988)

Well, this was a long and very exciting dive. We flew over the basaltic floor to see what the regular seafloor looks like, we observed strange and fascinating biological communities that thrive in a very toxic environment (hot water, complete darkness, toxic minerals such as Zn, Cu etc...), we sampled black smokers, we photographed active sulfide deposits forming right in front of our eyes, and finally discovered one of the tallest sulfide structure in the Pacific Ocean. It is 3:30 pm now and we are running out of battery power. It is time to pull the plug and go back to the surface. The pilot drops the last weights and the sub slowly starts on its journey toward the sunlight. The scientists can now relax for a while, and stretch their legs which are starting to be very painful now. During the dive the nervous tension of the work to accomplish and the excitement of witnessing an environment in which very few people will ever go kept us from thinking how uncomfortable this little sphere can be. But, now we feel tired and cold, and we would like to breathe fresh air for a change. But, what a fantastic dive! and what a thrill to be able to come close to all the wonders we have seen today! After about 1 .5 hour we are back at the surface, it takes a few minutes for the ship to come close enough to attach the sub to the cable that will drag it back in alignment with the A-frame. A few more minutes to be lifted off the water and put on board safely. Then the hatch will be open and we’ll get out to share our experience with the other 1 7 scientists that did not get to dive today. The pilot will go over everything on the sub. He already is getting ready for tomorrow’s dive. We are now checking our samples and removing them from the basket for analysis, as work on the ship goes on round the clock.

This sample of tube worms was collected during the dive and we have just put them in a plexiglass box to take pictures before the biologists on board start studying them. It looks like they survived the trip to the surface rather well. Some of them are still alive but unfortunately not for long because this water is nothing like the fluid they need to live and thrive.

Slide 26 Results from the dive (photo by V. Robigou, 1995)

In this wooden box the pilot collected a large sulfide piece covered with biological communities. With this sample, biologists will be able to count individuals and start estimating what kind of populations live on sulfide rocks from the hydrothermal vents. The geologists will be able to study the mineralogy of the rock which serves as support for the biological communities. Together, biologists and geologists might be able to find correlations between the type of geology, the temperature of the fluids and the type of animals living in this exceptional environment.

Slide 27 Results from the dive (photo by V. Robigou, 1995)

Close-up of the worms collected in the previous sample. On the grey background of sulfide you can see white tubes in which sulfide worms live and red palm worms which also live on sulfide deposits. These worms once counted and carefully identified will then be frozen to be sent to specialized laboratories where more extensive analyses will be performed.

To close this incredible journey through the sea and to the bottom of the ocean, I would like to show you a short movie taken during a dive in the area that you have been introduced to today. This video was taken with a color camera mounted not on the ALVIN submersible but to the remotely operated vehicle Jason which is also used in deep-sea exploration and research. The video will show spectacular footage of the black smokers we have discussed today.

Slide 28 Veronique photo

This picture was taken on board the Research Vessel *Atlantis II* which carries the manned-submersible Alvin. I was participating in a twenty Alvin dive cruise on the Juan de Fuca Ridge, the spreading center located off the coast of Canada and the Washington and Oregon states in the north east Pacific Ocean. It is June 16, 1995, a sunny day on the deep ocean.

How did I end up exploring the ocean floor in small submarines and doing research in marine geology?

I was born and grew up in France and followed a typical path through the French educational system of the 70s. I was always interested in natural sciences in school as well as in every day life (collecting animals, leaves, plants, rocks etc...). One of the turning points of my life was a trip to the United States during the summer of my 10th birthday during which I not only learned English, but was also exposed to a different culture and to my first experience with scientific research.

My uncle was a cancer researcher at the time and lent me a microscope with slides of skin cells to examine. It fascinated me even though I did not quite realize that I was looking at his latest research. More importantly, he gave me a couple of mice that were used in some of his experiments to take care of, which I did with eagerness. During that summer, not only did I decide to be a scientist (a medical researcher at the time) since my uncle was trusting me with part of his real experiment, but I also realized that things did not have to be done exactly the way I was told or shown in my own culture; it was possible to do things differently elsewhere.

Throughout my middle school and high school years, I enjoyed natural sciences the most but also spend a lot of time perfecting my English and enjoying all the other subjects. It became clear that although I was doing better in natural sciences than any other subject, I just enjoyed learning and liked discovery in anything French, languages (English, Latin and German), history, geography, physics, music, drawing and painting. Learning new concepts and ideas in any field fascinated me and it was going to be difficult for me to choose which way to go after school. But, deep down, I knew I would probably pursue a scientifically-oriented career and would like to go back to the United States (I was still dreaming about becoming a cancer researcher).

My family was always supportive even though my parents did not have the chance to go to college and my grandfather, who presented the image of a strict, stern physics professor, always encouraged me to do whatever I thought I wanted to do even if, at the time, a lot of careers were not yet open to women. I never once felt this was (let this become?) an obstacle. I was raised thinking that anybody could do anything and if they worked hard at it they would succeed.

During my high school years, I persuaded myself that I would be financially independent and would opt for a working life. It seemed the only way for me to feel complete as a human being as well as have a place in society. Even though I was always shy, I was fiercely independent (some probably described it as stubbornness). I would listen to advice from teachers and family but would never give up my own sense of what was good for me. In 10th grade, despite everybody's recommendations, I decided to get a natural sciences high school diploma instead of the math diploma which was considered the most prestigious. I also got a scholarship to spent my 12th grade year in England, despite the reluctance of some of my teachers who thought it would be better to stay in my home school to finish my education. I was 16 years old and spent my last year of high school studying in London. I graduated with honors and received my high school diploma which entitled me to pursue college studies.

At this point, I was fascinated by human biology, languages and philosophy as well as by natural sciences in general. I applied to the Forestry and Agricultural School, a private school forming forestry engineers, but was not accepted. Disappointed but not discouraged, I enrolled at the university in the natural sciences bachelor's program thinking I would love the biology and genetics classes. But, the biology professor turned off my interest in biology.

In contrast, I had a fantastic geology professor who was able to share his enthusiasm for rocks and understanding of the formation of the earth with 600 students every week. I was hooked and never looked back. My second year I declared a geology major and went on from there. After receiving my bachelor's degree, I went on to do one year of research at the University of Toulouse and starting looking into future jobs in my specialty. After several summer months working for mining and oil companies, it became clear that being a woman geologist was not quite as easy as I had expected.

To get a better idea of what was possible elsewhere I traveled to the United States to investigate possibilities there and had interviews at Shell, Exxon and other companies. Since I was in the States, I also checked out graduate schools and was impressed by the learning environment in American universities. Although very competitive, they were more flexible and student oriented than French universities.

After thinking about all these experiences, I finished my thesis and I decided to go to graduate school in the US since I did not feel I could adapt yet to the day to day work routine of industry. I still needed to grow and have free time to do so. I was accepted to the department of Earth and Space Sciences at UCLA and got a master's degree. It was very hard to come to another educational system, use another language and be as competitive and competent as some of the students at UCLA. The department, students and professors were very supportive and with a lot of work I graduated with a Master's in Geology in 1984. By that time it was also clear that I was probably going to stay in the US for quite a while since I had met my future husband at UCLA. He is also a geologist.

Now, that I had the background and the motivation I needed to do geology, we both had to find jobs that would enable us to continue with our professional interests. Another challenge! Bruce, my husband, found a faculty position at the University of Washington after he graduated with a Ph.D. in geology and, at the same time, he was offered a post-doctoral position in France for a year. We decided to go to Paris for a year and then move to Seattle.

In France, I worked part-time for a Canadian mining company and went to the university to continue research while Bruce worked at the university. We also got married during that year in France. In 1986, we moved to Seattle where Bruce started his position in the Department of Geological Sciences at the UW and I tried to figure out what was next for me.

First, I had to adapt to a new city and start from scratch in a country where I had had a good time but in which I did not quite fit culturally. Jobs in geology were scarce in the area and I ended up getting an interview for a technical position with a professor of marine geology at the School of Oceanography. I started working as an hourly employee doing a lot of organization for the research group this professor was leading. I had to learn quickly about marine geology as I went along since this was not a specialty I knew much about. Little by little and thanks to the encouragement of the research team leader, I became involved in oceanographic cruises, diving and finally research. I have been with this group for 9 years now and still love it. Lately, I have also devoted more of my time to educational activities such as the slide show you are using today

Photographs taken by:

J. Delaney, R. Holcomb and V. Robigou, marine geologists, School of Oceanography, University of Washington.

M. Smith, engineer, Department of Geological Sciences, University of Washington.

P. Hickey, ALVIN pilot and 1995 expedition leader for the ALVIN

dives,

ALVIN external cameras, Woods Hole Oceanographic Institution.

Video extracts from Crest-1991 expedition on the Juan de Fuca Ridge, first scientific expedition using the Jason ROV, University of Washington and Woods Hole Oceanographic Institution.